VARIATIONS IN THE NORMAL RANGE OF CHILDREN'S VOICES; VARIATIONS IN RANGE OF TONE AUDITION; VARIATIONS IN PITCH DISCRIMINATION

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CONTENTS

CONTENTS (Contd.)

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Nature of the Investigation

The following is an account of an investigation carried on in the Psychology Department of Edinburgh University under the direction of Professor Drever. The subjects of the investigation were thirty children of average age ten years six months; pupils in the Middle Senior class in one of the Edinburgh Education Committee's Primary Schools.

The subjects were individually examined in:

I. (a) Pitch-discrimination
   (b) Upper Limit of Tonal Hearing
   (c) Lower Limit of Tonal Hearing
   (d) Speaking Voice
   (e) Singing Voice.

The children were given as a group:

II. (a) An Intelligence Test
    (b) Attainment Tests in several subjects.

Apparatus/

Apparatus

The apparatus used in I :

(a) Spearman's dichord with the constant wire tuned to A above middle C (a' = 439 d.v.)

(b) An Edelmann-Galton whistle of the steam-whistle pattern.

(c) Three Edelmann forks.

(d) and (e) A pianoforte tuned in New Philharmonic pitch.

Tests (written)

The tests employed in II:

(a) Otis Group Intelligence Scale. Primary Examination: Form A.

(b) Edinburgh Education Committee's Attainment Tests in: Reading, spelling, vocabulary; addition; subtraction, multiplication and division.

Examination of Apparatus and Technique

Spearman's Dicord:

This consists of:

(a) A steel frame supporting two pairs of tuning keys.

(b) Two wires; each held at any desired tension by a pair of keys.

(c) /

(c) Sliding adjustable clamps fitted with verniers and moving upon a millimetre scale. By their means the length of the vibrating part of the wire can be varied and adjusted correctly to 0.1 mm.

The constant wire or "standard" was tuned to a' of 439 v.d. and retained at that pitch. Sounds to be compared with the "standard" were obtained from the other wire - the "variable" - by altering its vibrating length. In succession, the two sounds were heard and the subject - seated with back to dichord - then declared whether the second one was "higher," "lower," or "same." The Method of Limits (complete ascent and descent) was employed in those tests, and the two possible orders of presenting the sounds utilized.

<u>Necessity of careful administration</u>: When using the dichord in pitch discrimination tests it is essential that special attention be paid to the following points:

<u>Intensity</u>: The wires must be sounded with equal intensity because poor discriminators are liable to confuse loudness with pitch and as a consequence frequently declare the louder sound to be the higher of the two.

The wires should be sounded with just sufficient loudness for the subject to hear clearly. If this is exceeded, then small pitch differences - apparent/

apparent with softly sounded wires - become very difficult and even impossible to distinguish.

<u>Duration</u>: Each sound should be heard for the same period of time and the interval separating them should be of similar length. Seashore(1)[x] considers that the most satisfactory time unit is that of one second. Whipple(2) regards this as rather short and recommends the use of two seconds. In the present investigation the longer time unit was preferred.

<u>Quality</u>: The sounds presented for comparison must have identical tone-qualities. A slight quality difference can influence a subject markedly.

Some time ago I investigated this point by examining a number of children in pitch discrimination, using for the purpose, wires possessing a small quality difference in their respective tones. From the results obtained the following conclusions were drawn:

1. When the tone-quality of the wire used as "standard" was slightly brighter than that of the "variable" then the lower DL of almost every S. was smaller than the upper.

in case of same contrast ?

2. When the timbre of the "standard" was rather duller than that of the "variable" the upper DL was the smaller. This appeared to be the case irrespective of time order.

The reason for this is as Myers(3) states: "A tone/

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[x] See Bibliography.

tone which is poor in overtones not only has a duller timbre, but actually appears to be lower in pitch than a tone rich in overtones."

Edelmann-Galton whistle: Myers,[4] who examined various types of limit whistles described a whistle, of the same pattern as that used in this investigation, as follows: "A Galton whistle has been made by Edelmann of Munich on the principle of the locomotive steam-whistle. The whistle-pipe is separated from the mouthpiece, at the lower end of which the air issues from a minute annular slit. The distance or mouth-breadth between the slit and the upper end of the pipe, on which the escaping air impinges, can be varied by means of a micrometer-screw. The pitch of the note is determined by the mouth-breadth as well as by the pipe-length. Each whistle (not only each whistle-length) has its optimum mouth-breadth."

With each of those whistles a table was supplied giving the various readings and corresponding frequencies. The whistle used in this investigation was stated to be capable of producing sounds ranging in pitch from a^4 of 3,480 v.d. to a sound of 48,000 v.d. Obviously, this claim and the readings themselves required to be verified, before any tests could be begun. Could the whistle produce sounds of such frequency; and did the whistle readings correspond to the pitches assigned to them in the table/

table? Those were questions which could only be answered by carrying through standardizing tests.

Before proceeding to give an account of those tests it must be mentioned that Edelmann stated that the best source of air for the whistle was from a small rubber ball, held in the hollow of the hand, and, to quote from his booklet, "By squeezing (this) fairly strongly with the tip of the thumb sufficient pressure is obtained." It must be noted that he specifies no definite pressure. In his table of whistle readings and corresponding vibration numbers it is only mentioned that such were established at a temperature of 15° Centigrade, but nothing is said of the pressure or pressures used. The only reference which he makes to this is where he declares that in whistles of the steam-whistle pattern the pitch is practically unaffected by changes in wind-pressure. This, as Myers has shown and which I have myself verified is not the case; the pitch being very much dependent on the wind-pressure employed.

This disregard of pressure can be shown to be the source of the further error made by Edelmann[5] who, having examined the hearing of a large number of subjects stated: "With these improved whistles, it can easily be shown that the extreme limit of hearing extends for many persons to 50,000 v.d. or even somewhat higher." Actually, the average upper tonal limit of those subjects would be in the neighbourhood of 20,000 v.d. How then did Edelmann arrive at such a/

a conclusion? The cause lay in the source of air employed. Wind pressure available from the compression of a small rubber ball is neither at an immediate maximum nor is it constant. The "sufficient pressure" of which he writes actually builds up from zero and rapidly diminishes again. Edelmann evidently was not aware that in those two periods - namely before reaching the maximum, and after that point - there were occasions of slight pressure and that in each of those periods the whistle produced a sound quite different from that obtained when the pressure was at its greatest; a sound of short duration and of very much lower pitch lying well within the range of hearing of his subjects.

Edelmann's results regarding the upper tonal limit of hearing are as a consequence incorrect.

Dr. H. Macnaughton Jones(6) of Edinburgh after having visited Edelmann in Munich subsequently contributed an article, which appeared in the Edinburgh Medical Journal, on the Edelmann-Galton whistle. He apparently accepted Edelmann's results on the upper limit of tonal hearing as being correct, and as a consequence, fell heir to the various errors made by Edelmann. No attempt was made at determining the air pressures necessary for the production of the various frequencies, but "sufficient pressure" continued to be obtained from a small rubber ball. Thus it was that he wrote: "Having examined the hearing of a number of persons with assumed normal hearing I have/

have found that a small proportion can reach from 45,000 to 50,000 v.d. per sec., and a very large number from 37,000 to 40,000."

Myers,[1] who made a careful examination of the new Edelmann-Galton and other forms of this limit whistle reached the conclusion that: "In all varieties of Galton whistle the pitch of the tones varies with the pressure of wind employed." Many examples are given by him of such variations in pitch caused by changes in the air pressure. To mention only one: The Edelmann-Galton whistle which he used was stated by Edelmann to produce, at one particular reading, a tone of 28,000 v.d. per second irrespective of the pressure employed. Myers found that with that reading it was possible to obtain tones ranging in pitch from 5,000 v.d. to more than 28,000 v.d. by altering the pressure of air.

Standardizing Tests: Standardizing tests were carried through on the Edelmann-Galton whistle used in this investigation.

To examine the lower part of its range - from approximately 3,500 v.d. to 9,500 v.d. - cylindrical brass rods of various lengths were used. Those rods were clamped at nodal points: this determined their mode of vibration.

By stroking lengthways with a resined cloth a rod/

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[1] Myers, op. cit.

rod was set into longitudinal vibration and emitted a clear and ringing tone of a frequency calculated from the formula:

$N = \frac{V}{\lambda}$ where N = Frequency of the sound.
V = Velocity of sound in the rod.
λ = Wavelength of sound in the rod.

Before this formula could be employed, it was first necessary to find the value V. This was obtained from:

$V = \sqrt{\frac{E}{\rho}}$ where E = Young's Modulus for the rod.
ρ = Density of the rod material.

Young's Modulus was determined experimentally[1]; the formula used in the calculation being:

$$E = \frac{1}{4} \cdot \frac{M}{x} \cdot \frac{al^2g}{\pi r^4}$$ [2]

The value obtained for E was $1{\cdot}1 \times 10^{12}$ dynes per square centimetre.

It/

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[1] The Statical method was used. For details regarding this consult:
Searle, G.F.C. Experimental Elasticity. Cambridge: University Press, 1933, 186 p.

[2] This is the formula for a cylindrical rod.
M = Mass in grams.
a = Distance from knife-edge to point of application of load.
l = Length of rod between the two knife edges.
x = Deflection in cms.
r = Radius of rod.
g = The acceleration due to gravity, being 981 cm. per sec.^{2} in the British Isles.

It was also necessary to ascertain by experiment the density of the material of the rod. This was found to be 8.70 grams per c.c.

The Wave-length of the sound was obtained from careful measurement of internodal distance on the rod.

When a rod was sounding, the Edelmann-Galton whistle was adjusted to produce a unison tone. This tuning was comparatively easy to do, as, when nearing the unison, shrill beating occurred which became slower and ultimately disappeared when the true sound was reached: moreover, the frequent presence of difference tones further simplified the process.

The air-supply for the whistle was from a constant-pressure blower in the laboratory. A water manometer[1] was used for measuring the pressure.

By this method, the whistle was examined over a range from 3,500 v.d. to 9,500 v.d. The air-pressure used was that required for the production of a clear steady tone: this proved to be equal to 250 mms. of water. With that pressure, it was found that the whistle-lengths necessary for producing unison sounds with the tones produced by the rods were in accord with those given in the table of values[2].

A point made evident during those tests on the Edelmann-Galton whistle was the close connection

between/

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[1] Each limb of the manometer was 1.36 metres in length.

[2] For comparison, two graphs were drawn plotting frequency against whistle-length; one being constructed from the Edelmann table of values, and the other from the results of the tests.

between pitch of sound and the air-pressure used: when increased, the pitch rose and when decreased, it fell. This was clearly demonstrated, as the whistle-length had to be altered on those occasions to obtain a sound in unison with that of the rod.

For frequencies above 10,000 v.d. the degree of accuracy of the whistle was tested by means of Schwendt's(7) application of Kundt's dust-method.

Cork dust was used for frequencies as high as 15,500 v.d.. Beyond this, Lycopodium - on account of its extreme lightness - was employed.

The lengths and diameters of the glass tubes, in which the powder-figures were produced, were in accord with the recommendations of Koenig(8).[1]

The method of supplying air to the whistle was changed for those tests. As the constant-pressure air-blower was a laboratory fixture and consequently not available for use in the sound-proof room, it was considered advisable that in carrying through standardizing tests which would cover that part of the whistle-range in which, for the majority of persons, the upper limit of tonal hearing lies, an air source should be employed/

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[1] "The tubes used for the tones from c^5 to c^7 should have a length equal to that of 100 half-wave-lengths of the sound being produced; but above c^7 must correspond to a smaller number of half wave-lengths, and indeed in the middle of the octave from c^8 to c^9 dare not exceed more than forty.

The diameter of the tube for the tone c^5 should be the same as the length of a quarter wave, but from c^5 to c^6 should increase to be equal to the length of a half-wave and above this tone up to the highest tones should increase but only until it is about two-thirds of the whole wave-length."

employed which would be serviceable in the sound-proof room when the actual hearing tests were begun.

For this purpose, a size six double bellows as used in Paquelin's cautery was ultimately selected as the most satisfactory method of supplying air to the whistle. The ease with which it could be manipulated was a great asset, and moreover, it was capable of supplying air over a much wider range of pressure than had been possible by the previous method.

In conjunction with the double bellows, a water manometer was used for pressure readings.

Air was supplied to the whistle at a constant pressure - evident from the steadiness of the water column - and moreover it was possible to prolong the whistle sound for any length of time.

Regarding such prolongation Koenig[1] writes as follows: "The audibility of the highest tones depends not only on their vibration number and intensity but also considerably depends on their duration, for people who otherwise could only hear c^7 and d^7 perceive pipe tones up to g^7 although not at the moment when the pipe begins to sound but after its tone has acted on the ear for some time."

Using the method of powder-figures[2] the whistle was examined over a range from 10,000 v.d. to 48,000 v.d. per sec.

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1 Op. cit., 11 f.

2 W. König's explanation of the striations in Kundt's tubes is given in Lord Rayleigh's Theory of Sound. London: Macmillan and Co., 1926, vol. 2, p.46-47.

As Edelmann's table of whistle-readings had been established at a temperature of 15°C, the standardising tests were always carried through at that temperature.

The wave-lengths of the sounds - obtained by measurement of the figures - and their corresponding calculated frequencies[1] agreed highly with those given by Koenig.

That the whistle was capable of producing sounds as high as 48,000 v.d. was found to be the case. But whereas Edelmann had assumed that identical air pressures/

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[1] The formulae used were:

(1) For the calculation of the velocity of sound in free air at a temperature of 15°C. :-

$$V_t = V_0\sqrt{(1 + 0{\cdot}004\, t)}$$

Where V_t is the velocity of sound in air at a temperature t.
V_0 the velocity of sound at 0°C. (33060 cm./sec.).

(2) For the calculation of the velocity of sound in the narrow tubes used for the powder-figures, the formula calculated by Dr. Veillon, from those of Helmholtz and Kirchhof, for Schwendt, was employed:

$$c = C\left(\frac{1-\gamma}{2r\sqrt{\pi N}}\right)$$

"where c is the velocity of sound in narrow tubes.
C = the velocity of sound in free air.
γ = A constant calculated by Professor Kaiser of Bonn.
$2r$ = The diameter of the tube used.
π = The known constant 3.1415926.
N = The vibration number.

The vibration number being as yet unknown the theoretical vibration number is used; the error is infinitesimal. Professor Kaiser found the value for γ to be 0.0235." Op. cit., 11f.

pressures could be utilized over the entire whistle range, it was found from this examination that progressively greater pressures had to be employed as the produced sounds increased in frequency.

For the production of powder-figures corresponding to a frequency of 10,000 v.d. it sufficed to use a pressure equal to 250 mms. of water whereas for 48,000 v.d., 1,000 mms. was necessary.

For the various frequencies between those limits it was necessary to use several pressure-values.

A table of those values was then compiled so that all the children who were subsequently examined in the investigation of their upper limits of hearing had presented to them, sounds, produced under similar conditions of pressure.

The only varying factor was the temperature of the air in the sound-proof room. As it was not possible to regulate this, temperature readings were taken during hearing tests and the necessary corrections[1] made when calculating the upper limit.

The/

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[1] $n_2 = \frac{n_1 \sqrt{T_2}}{16 \cdot 97}$ Obtained from $\frac{n_1}{n_2} = \frac{\sqrt{T_1}}{\sqrt{T_2}}$

where n_1 = Frequency at 15°C.

n_2 = Frequency at any temperature t.

T_1 = 288°C. (i.e., 15° + 273° absolute temp.).

T_2 = 273° + t°C.

The one disadvantage of the Edelmann-Galton whistle is the inability to vary the intensity of a sound without disturbing its pitch.

This is noteworthy because with increase of intensity a subject's upper limit of hearing may be raised slightly.

Apparently, however, this fact regarding the Edelmann-Galton whistle does not appear to be universally recognised since in a report (9) published only a few years ago the following statement regarding the whistle occurs: "Although the pitch is not varied by the force of the air current, the intensity is."

Apart from correct whistle-length and proper air pressure it is necessary to make sure that the specified mouth-width for any particular frequency is used. The reason for this is because the whistle like many musical instruments is what has been termed a "coupled system." This means that present in its sound is a strong whistle-tone and a feeble edge-tone. When functioning properly, the former forces its frequency upon the latter: but, if those two systems become loosely coupled - frequently caused by using the wrong mouth-width - the component sounds become distinguishable in pitch.

Richardson (10) has described, with illustrations, the formation of air eddies in an edge-tone.

This examination of the Edelmann-Galton whistle has been dealt with at some length because it is still regarded/

regarded by otologists as a reliable instrument for the study of the upper limit of tonal hearing.[1]

In carrying through the actual hearing tests, the subject sat at a distance from the whistle of approximately half a metre; the whistle being situated to the subject's left.

As each child examined could hear equally well with either ear, it was decided to test in every case the left one. The unused ear was left open as it was considered that the use of a plug would distract the child's attention. For a similar reason a chin-rest was not employed but instruction was given so that a constant position was retained by the child during the tests.

The Method of Limits was used.[2]

<u>Edelmann Forks</u>: Three giant Edelmann forks were utilized in the investigation of the lower limit of tonal hearing. Adjustable sliding weights were attached to each prong and by setting those weights at the inscribed vibrational readings it was possible to obtain/

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1 In air conduction. It is impossible to use a whistle for ascertaining the upper limit in bone conduction.

2 For complete explanation of the method consult: - Titchener, E.B. Experimental Psychology. New York: Macmillan, Vol. II: parts I and II. 1905.

obtain the following range:

On the largest fork, from 12 v.d. per sec. proceeding by intervals of .5 of a double vibration to 18 v.d. per sec. The middle-sized fork produced from 16 v.d. per sec. to 24 v.d. per sec., the steps being of 1 v.d. In the case of the smallest fork the range was from 24 v.d. by 2 v.d. to 36 v.d. per sec.

With regard to those forks two questions arose: First, did they produce the low frequencies ascribed to them? Second, were the tones of the forks simple or compound?

To investigate the first of those - the question of correctness of frequency a slow-motion film was taken of the largest fork in vibration with the weights on the prongs set at the inscribed reading of 16 v.d. Before this film was taken the camera was first examined to make certain that its speed of 64 frames per second was accurate.

Immediately behind the prongs was a horizontally fixed metre scale with two broad dark bands marked upon it.

(Fig. 1 over) /

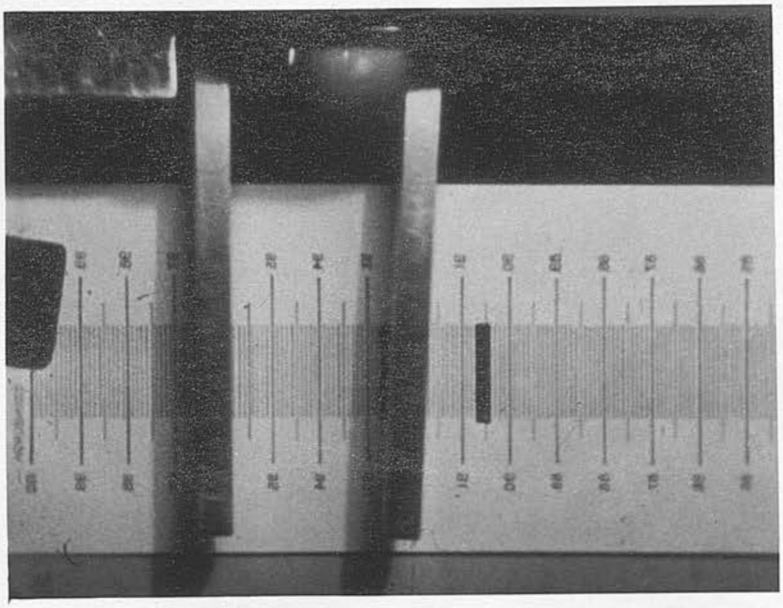

Fig. 1. Weighted Tuning Fork in Vibration

When this film was projected and examined frame by frame (see Fig. 1) it was seen that in every series of four frames each prong of the fork made one complete vibration, that is to say, one double vibration took place every sixteenth of a second, thus showing that the frequency of the large fork at that setting was correct.

Having ascertained this, it was then necessary to examine the other forks against the large one to find if the various sounds which they produced, by altering the position of the sliding weights, corresponded to the frequencies inscribed on the prongs. This was done by energizing[1] two forks - one being the large tuning fork set at the reading of 16 v.d. - and/

[1] The forks were actuated by striking with the gloved hand.

and observing the beating produced as a consequence of the difference in frequency between the forks.

Having been set into vibration, the forks were held by the stems in suspended position so that the flat surfaces of corresponding adjustable weights were directed towards the opening of the external auditory meatus of the same ear and as closely as possible to it.

By so doing, it was possible to distinguish two sets of beats: the first, caused by the Fundamentals, and the second - as they were at double the speed - evidently produced by the beating of Octave vibrations. Every alternate beat of the second set coinciding with a beat of the first set served to accentuate it. In some instances it was noticed that after the forks had been vibrating for a few seconds the weaker beating caused by the octaves disappeared entirely.

The foregoing shows the necessity, when carrying out tests in the lower limit of hearing, of giving the subjects sufficient practice to enable them to distinguish the fundamental from the octave vibration that usually accompanies it.

It was evident from the results obtained by those tests that the medium-sized and the smallest of the three Edelmann forks did produce sounds corresponding in frequency to the vibrational markings.

In addition to the tests already mentioned, the forks were given a further examination. A slight modification/

modification in the method employed was the only difference from the previous procedure. Instead of suspending the forks when they were in vibration, they were now held with their stems pressed upon a small table.

As before, two sets of beats were distinguishable, but it was now observed that the beating of the octave vibrations was much stronger than that occasioned by the fundamentals. This was the reverse of what took place when the forks were held suspended in the air.

Proceeding from this a stage further, it remained to be ascertained if there was any effect on the sound of a single fork when set into vibration and placed with its stem upon the table.

In every case it was found that the octave above the fundamental was the sound heard; the fundamental itself being entirely overshadowed.

Lord Rayleigh,[11] Helmholtz,[12] and Ellis[13] have each made observations on the nature of the sounds emitted by tuning-forks of very low pitch.

The predominance of the octave in such cases is a point which must be noted. When Bezold[14] in his investigation of the lowest audible tone used Edelmann forks he placed the stem - of the largest fork - upon a table and allowed the subject to lay his head against the latter.

The sounds heard, he asserted, were the fundamentals entirely free from octave vibrations. It is consequently/

consequently obvious that Bezold's statement that some people with normal hearing were able to perceive a low tone of 11 v.d., is incorrect. Although his fork was set at that vibrational reading his subjects were actually hearing an octave vibration of 22 v.d.

Bezold's contention that the Edelmann forks produced simple tones was based upon the sinusoidal curves which he obtained as traces on rotating smoked-drums from a style attached to a prong of the vibrating fork. As a result he concluded that no octave could be present in the sounds emitted by those forks. Apparently, he failed to recognise that a mere examination of prong movement did not justify such a conclusion.

Bezold's statement regarding the nature of the curves obtained from the forks was verified in the present investigation. On smoked drums driven by an electric-motor, the style traced sinusoidal curves in every instance. Photographs of those curves are shown in Figs. 2, 3 and 4.

Fig. 2 (over) /

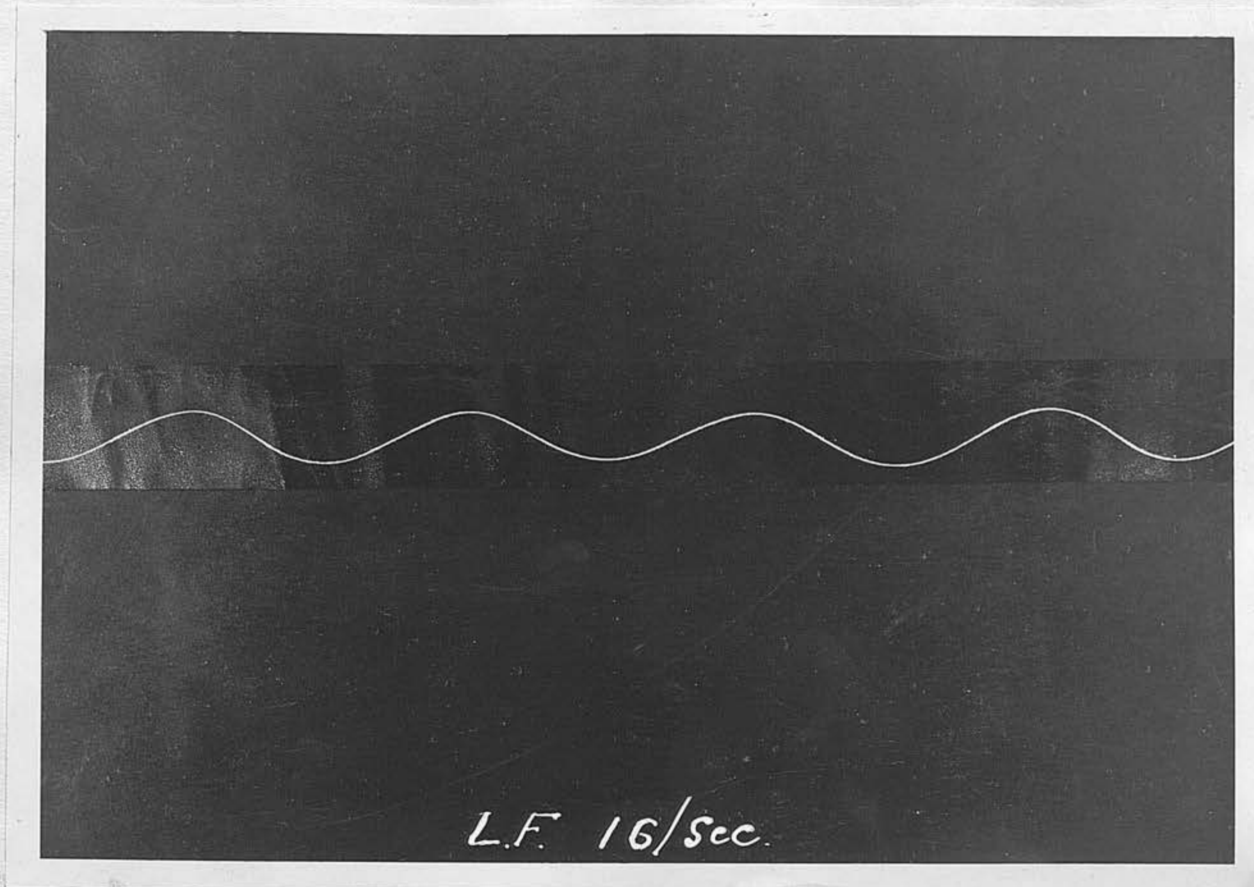

Fig. 2. Trace by Large Fork vibrating at 16 v.d. per second.

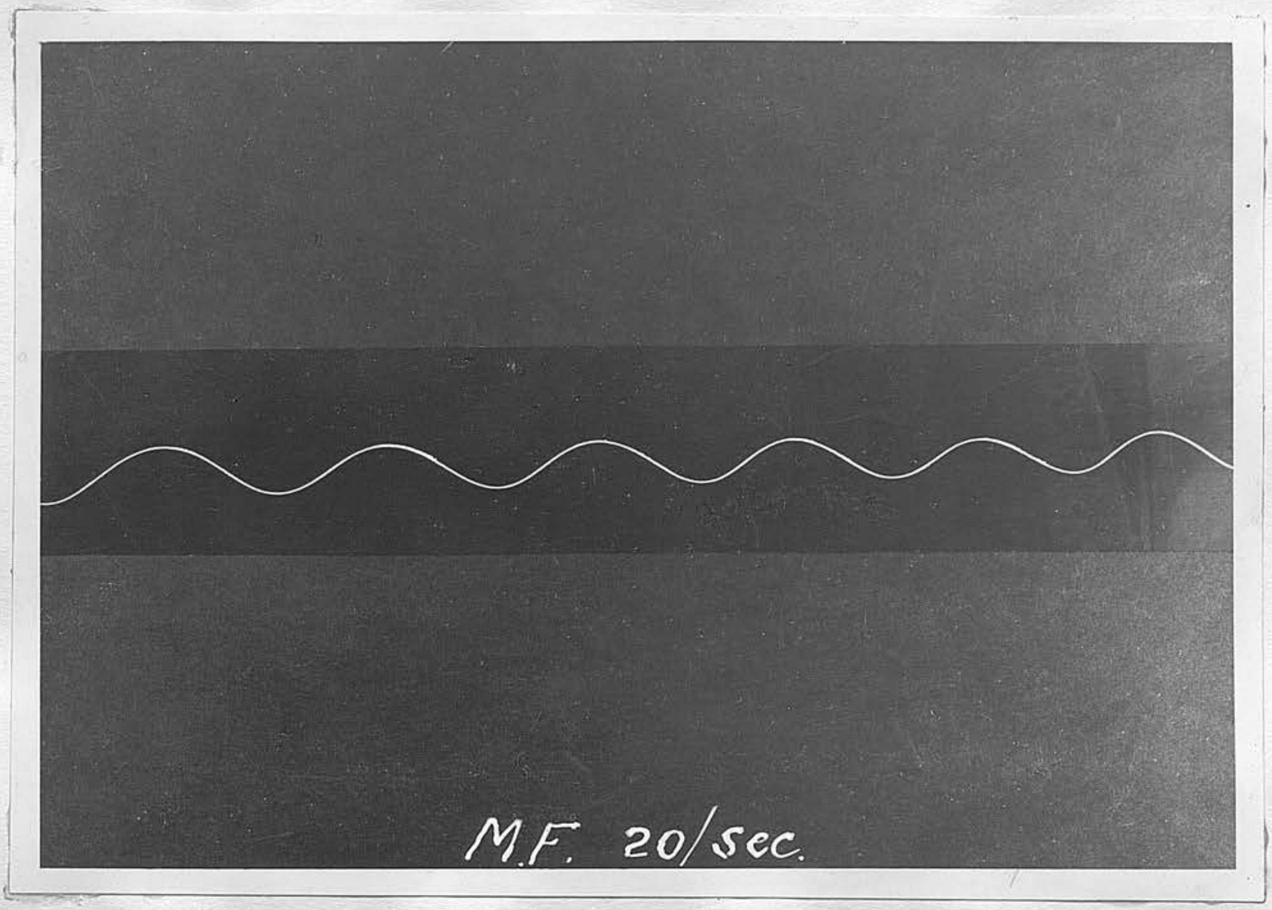

Fig. 3. Trace by Middle-sized Fork vibrating at 20 v.d. per second.

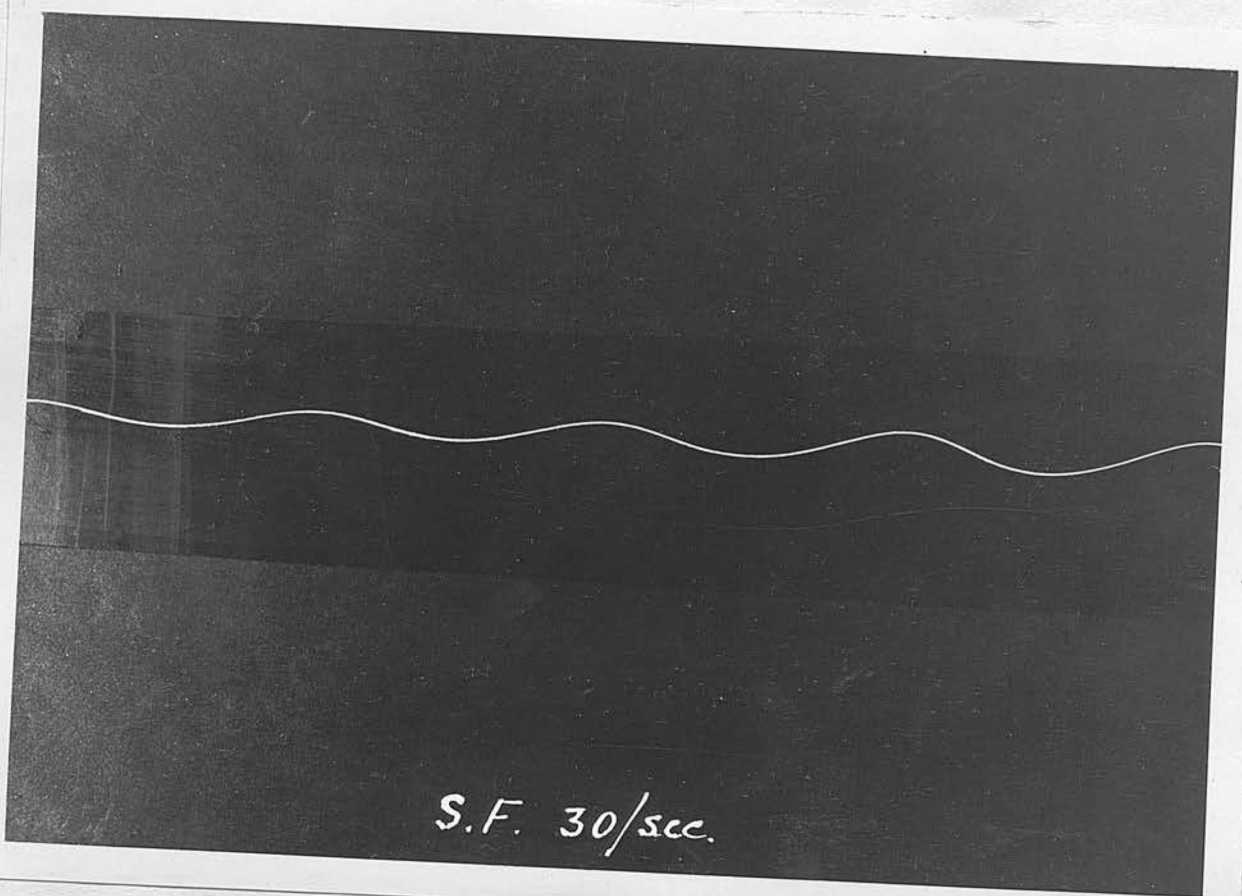

Fig. 4. Trace by Smallest Fork vibrating at 30 v.d. per second.

Schaefer,(15) who obtained similar traces considered that the octave vibration arose in the air. Helmholtz[1] regarded as the causes, the construction of the human ear and the fact that the sharp edges of the vibrating prongs of a large tuning-fork produced in the air vortical movements which did not constitute a simple vibratory system.

As the octave was present in the sound perceived by the subject it was necessary when determining the lower limit of tonality to employ that means whereby the fundamental was made as audible as possible. This was accomplished by directing the relatively large surface of one of the weights towards the subject's ear, and as close to it as possible.

That the area of the vibrating surface is an important factor in this particular test of hearing has been shown by the investigation of Vance.(16)

It has already been mentioned that those large forks carried on each prong an adjustable weight by means of which various frequencies could be obtained. Miles(17) proved that although the weights were unequally set on the two prongs - even by so large a variation between the settings as 22 v.d. - the rates of vibration of both prongs were the same. The prong set at the lower reading appeared to have a slightly smaller amplitude than the other. In such cases the resultant/

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[1] Helmholtz, op. cit., 158f.

resultant frequency was approximately the average of the two settings. As the prongs produced sounds of identical pitch, Miles found that beats were never present.

When the forks are used in hearing tests any difference in the settings is so minute that it need not be considered.

As in the other hearing tests, the Methods of Limits was used.

<u>The Psychophysical Tests Compared</u>

(a) Upper tonal limit; (b) Lower tonal limit.
(c) Pitch Discrimination.

The children experienced little difficulty in the test for the determination of the upper tonal limit. They were soon able to separate the shrill sound of the whistle from the hissing noise of the escaping air. In the lower limit test, distinguishing between the fundamental and octave and between sound and mere throbbing of air were difficulties which combined to make this the most difficult of the three.

Individual differences were markedly in evidence in the pitch-discrimination test so that a general statement/

statement cannot be made. The final tests were never given until the child ceased to show improvement from practice.

Presentation of Data (over)/

Presentation of Data

TABLE I. LOWEST AUDIBLE TONE.

Subject No.	Age Yrs.	Age Mths.	Lowest Audible Tone [1] Boys	Lowest Audible Tone [1] Girls	Subject No.	Age Yrs.	Age Mths	Lowest Audible Tone Boys	Lowest Audible Tone Girls
15	10	6	15.9 ± 0.52		19	10	5	18.4 ± 0.92	
1	10	2	....	16.1 ± 0.21	30	10	8	18.7 ± 0.94	
16	11	0	16.6 ± 1.83		6	11	1	....	18.7 ± 1.30
3	10	7	....	16.9 ± 1.23	10	10	2	....	18.8 ± 0.73
17	11	2	17.0 ± 0.68		25	10	3	18.9 ± 0.78	
14	11	0	17.1 ± 0.47		7	9	8	....	18.9 ± 1.06
13	10	7	....	17.1 ± 0.57	8	10	3	....	18.9 ± 2.12
18	10	6	17.1 ± 2.2		28	11	1	19.0 ± 0.50	
4	10	0	....	17.4 ± 0.95	20	10	0	19.1 ± 2.7	
23	9	0	17.8 ± 0.61		26	10	11	19.2 ± 0.43	
5	10	3	....	18.0 ± 1.29	24	10	8	19.2 ± 0.49	
29	9	10	18.1 ± 0.38		27	10	4	19.25 ± 0.75	
22	10	9	18.1 ± 0.71		21	11	1	19.6 ± 1.84	
12	10	8	....	18.1 ± 1.14	11	10	8	....	19.7 ± 1.63
2	9	6	....	18.2 ± 1.04	9	10	6	....	20.2 ± 2.96

[1] Results are average values obtained from final tests.

The average of the lower tonal limits given in Table I. was 18.2 v.d. (M.V. 0.90 v.d.; range 15.9 to 20.2 v.d.). Of the boys, 47% and of the girls, 46% had limits lying below that frequency.

When the groups were considered separately the average of the boys' lower limits was 18.2 v.d. (M.V. 0.91 v.d.; range 15.9 to 19.6 v.d.), and that of the girls 18.2 v.d. (M.V. 0.89 v.d.; range 16.1 to 20.2 v.d.).

(Table II over) /

TABLE II. HIGHEST AUDIBLE TONE

Subject No.	Age Yrs.	Age Mths.	Highest Audible Tone [1] Boys	Highest Audible Tone [1] Girls	Subject No.	Age Yrs.	Age Mths.	Highest Audible Tone Boys	Highest Audible Tone Girls
16	11	0	20,400 ± 520		11	10	8	....	18,875 ± 780
1	10	2	....	20,000 ± 500	25	10	3	18,805 ± 420	
29	9	10	20,000 ± 538		7	9	8	....	18,800 ± 420
18	10	6	19,833 ± 777		27	10	4	18,700 ± 670	
15	10	6	19,750 ± 875		30	10	8	18,680 ± 286	
5	10	3	....	19,600 ± 560	3	10	7	....	18,590 ± 375
10	10	2	....	19,500 ± 335	14	11	0	18,250 ± 750	
24	10	8	19,500 ± 800		22	10	9	18,227 ± 793	
6	11	1	....	19,410 ± 746	20	10	0	18,083 ± 820	
23	9	0	19,409 ± 331		4	10	0	....	17,703 ± 870
12	10	8	....	19,357 ± 531	9	10	6	....	16,937 ± 483
17	11	2	19,256 ± 346		26	10	11	16,833 ± 444	
21	11	1	19,227 ± 397		19	10	5	16,666 ± 277	
13	10	7	....	19,227 ± 440	28	11	1	16,201 ± 526	
8	10	3	....	18,920 ± 600	2	9	6	....	15,512 ± 250

1 Results are average values obtained from final tests.

From those results, and also from observation of the ease or difficulty shown by the children during the test it can be stated that, as regards the lower limit of tonal hearing, neither group - boys or girls - exhibited a superiority in the perception of low-frequency sounds.

Consideration of Table II.

The average of the upper tonal limits in Table II was of the value 18,675 v.d. (M.V. 917 v.d.; extremes 15,512 and 20,400 v.d.). Above this frequency occurred the upper limits of 64.7% of the boys and 69.2% of the girls.

Regarding the groups separately, the averages estimated were as follows: Boys alone - 18,695 v.d. (M.V. 933 v.d.; extremes 16,201 and 20,400 v.d.). Girls alone - 18,649 v.d. (M.V. 900 v.d.; extremes 15,512 and 20,000 v.d.).

It is evident from the above that in this test as in the previous one, boys and girls did equally well: neither group showing any distinct advantage over the other.

When the results given in Tables I and II were correlated, r was found to be of low numerical value with a high probable error, thus indicating that no direct relationship appears to exist between the two capacities of perception.

TABLE III. PITCH DISCRIMINATION

Subject No.	Age		Limen in V.D.[1]		Subject No.	Age		Limen in V.D.	
	Yrs.	Mths.	Boys	Girls		Yrs.	Mths.	Boys	Girls
25	10	3	4.0		3	10	7	....	8.3
4	10	0	....	4.6	6	11	1	....	8.3
18	10	6	4.9		15	10	6	8.9	
2	9	6	...	5.1	10	10	2	....	9.0
19	10	5	5.3		16	11	0	9.3	
13	10	7	...	5.4	30	10	8	9.3	
1	10	2	...	5.7	8	10	3	....	9.5
12	10	8	...	6.3	28	11	1	9.7	
14	11	0	6.3		11	10	8	...	10.3
29	9	10	6.3		9	10	6	...	11.8
20	10	0	6.4		26	10	11	11.8	
5	10	3	...	6.7	27	10	4	12.0	
7	9	8	...	7.1	24	10	8	12.4	
17	11	2	7.3		23	9	0	17.0	
22	10	9	7.7		21	11	1	20.0	

[1] Results are average values obtained from final tests.

From Table III the following averages of thresholds were calculated: -

a) For boys and girls: 8.6 v.d. (M.V. 2.7 v.d.; extremes 4.0 and 20.0 v.d.).

b) For girls alone: 7.5 v.d. (M.V. 1.8 v.d.; extremes 4.6 and 11.8 v.d.).

c) For boys alone: 9.3 v.d. (M.V. 3.2 v.d.; extremes 4.0 and 20.0 v.d.).

d) For boys, omitting the two poorest discriminators: 8.1 v.d. (M.V. 2.2 v.d.; extremes 4.0 and 12.4 v.d.).

From a study of the results it was found that 69.2% of the girls and 47% of the boys had thresholds lowerthan the Mean stated in (a).

When the two averages shown in (b) and (c) were compared it looked as though the girls showed a superiority in sense of pitch but when the Probable Error of this difference in the averages was calculated it was seen that such a conclusion could not be drawn.

However, most of the girls reached the approximate physiological threshold after fewer practice tests than did the boys, many of whom required much instruction and practice. As this is made the subject of special inquiry in a subsequent part of the paper it will not be discussed further at the present stage.

Results of Written Tests

TABLE IV. INTELLIGENCE QUOTIENTS.

Subject No.	Age		I.Q.		Subject No.	Age		I.Q.	
	Yrs.	Months.	Boys	Girls		Years	Mths.	Boys	Girls
8	10	3	......	119.0	15	10	6	98.4	
4	10	0	......	116.6	16	11	0	97.7	
19	10	5	114.0		22	10	9	96.0	
3	10	7	......	110.2	26	10	11	96.0	
23	9	0	109.0		18	10	6	95.0	
2	9	6	......	108.7	17	11	2	94.7	
1	10	2	......	108.2	6	11	1	....	93.2
20	10	0	105.0		27	10	4	92.0	
5	10	3	......	104.8	7	9	8	....	92.0
10	10	2	......	104.0	9	10	6	....	92.0
29	9	10	103.0		24	10	8	89.0	
25	10	3	102.0		12	10	8	....	89.0
14	11	0	101.6		21	11	1	88.7	
13	10	7	......	101.0	28	11	1	87.0	
11	10	8	......	99.0	30	10.	8	87.0	

Consideration of Table IV.

Table IV yields the following: -

e) Average of Intelligence Quotients:
99.8 (M.V. 7.3 points; range 87 to 119).

f) Average of Boys' Intelligence Quotients:
97.4 (M.V. 6.0 points; range 87 to 114).

g) Average of Girls' Intelligence Quotients:
102.9 (M.V. 7.9 points; range 89 to 119).

The Probable Error of the difference between the boys' average and girls' average precluded the drawing of any conclusion regarding that difference.

The Tables which now follow give the results of the Attainment Tests. Subsequently, those results are used in establishing correlation coefficients.

Table V (over) /

TABLE V. ATTAINMENT QUOTIENTS IN READING

Subject No.	Age		A. Q.		Subject No.	Age		A. Q.	
	Yrs.	Mths	Boys	Girls		Yrs.	Mths	Boys	Girls
2	9	6	.....	130.0	24	10	8	103.8	
14	11	0	130.0		29	9	10	102.5	
5	10.	3	.....	125.0	1	10	2	.....	101.3
19	10	5	122.5		17	11	2	100.0	
25	10	3	120.0		6	11	1	.....	98.0
15	10	6	120.0		9	10	6	.....	98.0
20	10	0	118.3		28	11	1	96.0	
10	10	2	.....	115.0	11	10	8	.....	93.8
13	10	7	.....	115.0	26	10	11	93.8	
23	9	0	115.0		27	10	4	93.0	
3	10	7	.....	113.3	30	10	8	92.5	
18	10	6	111.6		8	10	3	.....	91.0
22	10	9	108.3		7	9	8	.....	88.0
4	10	0	.....	107.5	21	11	1	87.5	
12	10	8	.....	103.8	16	11	0	78.3	

From Table V the following averages were calculated: -

h) Average A. Q. in Reading: 105.8 (M.V. 11.4 points; range 78.3 to 130).

i) Average A.Q. of boys alone: 105.5 (M.V.12.0 points; range 78.3 to 130).

j) Average A.Q. of girls alone: 106.1 (M.V. 10.6; extremes 88 and 130).

Table VI (over)/

TABLE VI. ATTAINMENT QUOTIENTS IN VOCABULARY

Subject No.	Age		A. Q.		Subject No.	Age		A. Q.	
	Yrs.	Mths.	Boys	Girls		Yrs.	Mths.	Boys	Girls
14	11	0	130.0		3	10	7	.....	101.3
2	9	6	.....	124.0	26	10	11	100.0	
8	10	3	.....	116.6	12	10	8	.....	99.0
15	10	6	116.6		22	10	9	99.0	
23	9	0	116.0		29	9	10	99.0	
20	10	0	114.0		6	11	1	.....	97.0
25	10	3	114.0		9	10	6	.....	97.0
1	10	2	.....	113.8	7	9	8	.....	96.0
19	10	5	113.8		13	10	7	.....	93.0
5	10	3	.....	112.5	11	10	8	.....	92.0
18	10	6	108.8		27	10	4	90.0	
10	10	2	.....	108.0	21	11	1	88.0	
4	10	0	.....	107.0	28	11	1	88.0	
17	11	2	103.8		30	10	8	87.0	
24	10	8	102.0		16	11	0	79.2	

The following averages were estimated from the values given in Table VI: -

k) Average A.Q. in Vocabulary: 103.5 (M.V. 9.9; extremes 79.2 and 130).

l) Average A.Q. of boys: 102.9 (M.V. 11.0 points; range 79.2 to 130).

m) Average A.Q. of girls: 104.4 (M.V. 8.5 points; range 92 to 124).

The degree of reliability of the difference between averages (l) and (m) - as established by the magnitude of the Probable Error of that difference - indicated that although the girls' average was higher than that of the boys' a true difference was not shown.

Table VII (over)/

TABLE VII. ATTAINMENT QUOTIENTS IN SPELLING

Subject No.	Age		A.Q.		Subject No.	Age		A.Q.	
	Yrs.	Mths.	Boys	Girls		Yrs.	Mths.	Boys	Girls
1	10	2	....	122.5	7	9	8	....	100.0
14	11	0	120.0		10	10	2	....	98.8
3	10	7	.....	116.6	27	10	4	98.9	
4	10	0	.....	116.6	9	10	6	....	96.3
23	9	0	116.6		11	10	8	....	96.3
25	10	3	116.6		22	10	9	93.0	
20	10	0	115.0		26	10	11	93.0	
13	10	7	.....	115.0	29	9	10	91.3	
18	10	6	113.8		30	10	8	91.3	
2	9	6	.....	113.3	19	10	5	91.0	
15	10	6	112.5		12	10	8	....	90.0
8	10	3	.....	111.3	28	11	1	90.0	
24	10	8	108.3		21	11	1	90.0	
17	11	2	105.0		5	10	3	....	87.5
6	11	1	.....	101.0	16	11	0	87.5	

Consideration of Table VII.

The following averages were computed:

n) Average of the Attainment Quotients in Spelling: 103.3 (M.V. 10.5 points; range 87.5 to 122.5).

o) Average of boys' Attainment Quotients: 102.0 (M.V. 10.8 points; range 87.5 to 120).

p) Average of girls' Attainment Quotients: 105.0 (M.V. 10.0 points; range 87.5 to 122.5).

The difference between the averages (o) and (p) was found to have a Probable Error of a magnitude which showed that it could not be accepted as a true difference.

(Table VIII over)/

TABLE VIII. ATTAINMENT QUOTIENTS IN ENGLISH [1]

Subject No.	Age		A.Q.		Subject No.	Age		A.Q.	
	Yrs.	Mths.	Boys	Girls		Yrs.	Mths	Boys	Girls
14	11	0	126.7		24	10	8	104.7	
2	9	6	.....	122.4	17	11	2	102.9	
25	10	3	116.9		22	10	9	100.1	
15	10	6	116.4		6	11	1	.....	98.7
23	9	0	115.9		12	10	8	.....	97.6
20	10	0	115.8		29	9	10	97.6	
1	10	2	.....	112.5	9	10	6	.....	97.1
18	10	6	111.4		26	10	11	95.6	
3	10	7	.....	110.4	7	9	8	.....	94.7
4	10	0	.....	110.4	11	10	8	.....	94.0
19	10	5	109.1		27	10	4	93.9	
5	10	3	.....	108.3	28	11	1	91.3	
13	10	7	.....	107.7	30	10	8	90.3	
10	10	2	.....	107.3	21	11	1	88.5	
8	10	3	.....	106.3	16	11	0	81.7	

[1] The A.Q. in English "is held to be the average of the A.Q's in the Vocabulary, Reading and Spelling Tests."

Consideration of Table VIII.

The values calculated were as follows: -

q) Average of all the Attainment Quotients in English: 104.2 (M.V. 9.0 points; range 81.7 to 126.7).

r) Average of Boys' Attainment Quotients: 103.5 (M.V. 10.5 points; range 81.7 to 126.7).

s) Average of Girls' Attainment Quotients: 105.2 (M.V. 6.7 points; range 94.0 to 122.4).

Although average (r) is lower than average (s) the degree of reliability of the difference between those Means - as shown by the magnitude of the Probable Error - is not sufficient to indicate a true difference.

(Table IX over)/

TABLE IX. ATTAINMENT QUOTIENTSIN ADDITION

Subject No.	Age		A.Q.		Subject No.	Age		A.Q.	
	Yrs.	Mths.	Boys	Girls		Yrs.	Mths.	Boys	Girls
23	9	0	123.8		21	11	1	92.0	
3	10	7	.....	111.3	4	10	0	....	91.6
29	9	10	108.0		18	10	6	91.3	
17	11	2	103.3		16	11	0	87.5	
27	10	4	103.0		1	10	2	....	86.6
5	10	3	.....	101.0	6	11	1	....	85.0
15	10	6	99.0		7	9	8	....	85.0
10	10	2	.....	98.8	12	10	8	....	81.6
19	10	5	98.8		26	10	11	80.0	
25	10	3	97.5		28	11	1	80.0	
30	10	8	97.5		9	10	6	....	78.3
14	11	0	97.0		2	9	6	....	75.0
8	10	3	.....	96.3	20	10	0	73.8	
11	10	8	.....	96.3	24	10	8	72.5	
13	10	7	.....	95.0	22	10	9	70.0	

Consideration of Table IX.

From Table IX the following averages were computed: -

t) Average of the Attainment Quotients in Addition: 91.9 (M.V. 9.9 points; range 70.0 to 123.8).

u) Average of Boys' Attainment Quotients: 92.6 (M.V. 11.1 points; range 70.0 to 123.8).

v) Average of Girls' Attainment Quotients: 90.9 (M.V. 8.3 points; range 75.0 to 111.3).

The boys' average is here greater than that of the girls, but, as in previous cases, it is not possible to regard this as a true difference.

(Table X over)/

TABLE X. ATTAINMENT QUOTIENTS IN ARITHMETIC [1]

Subject No.	Age		A. Q.		Subject No.	Age		A. Q.	
	Yrs.	Mths.	Boys	Girls		Yrs.	Mths.	Boys	Girls
23	9	0	122.4		25	10	3	93.6	
3	10	7	.....	112.2	30	10	8	92.0	
5	10	3	.....	108.8	8	10	3	....	90.7
1	10	2	.....	108.2	11	10	8	....	90.3
29	9	10	103.7		4	10	0	....	89.3
10	10	2	.....	101.6	18	10	6	88.6	
7	9	8	.....	100.6	16	11	0	85.8	
15	10	6	100.3		2	9	6	....	84.5
17	11	2	99.8		24	10	8	83.6	
19	10	5	97.3		6	11	1	....	82.0
14	11	0	96.8		27	10	4	80.4	
21	11	1	95.0		12	10	8	....	80.3
13	10	7	.....	94.7	28	11	1	78.6	
9	10	6	.....	94.0	26	10	11	77.5	
20	10	0	93.6		22	10	9	72.0	

1 The A.Q's in Arithmetic were obtained in the manner prescribed in the Edinburgh Attainment Tests book of Instructions namely by adding the scores in addition, subtraction, multiplication and division then by reference to a table of norms reading off the Quotient corresponding to the composite score.

Consideration of Table X

Averages calculated from the results in Table X:

w) Average of the Attainment Quotients in Arithmetic: 93.3 (M.V. 8.7 points; range 72.0 to 122.4).

x) Average of Boys' Attainment Quotients: 91.8 (M.V. 9.0 points; range 72.0 to 122.4).

y) Average of Girls' Attainment Quotients: 95.2 (M.V. 8.6 points; range 80.3 to 112.2).

Although the girls' average is higher than that of the boys, the difference does not have a sufficient degree of reliability to justify a conclusion of superiority.

Correlation/

CORRELATION COEFFICIENTS and their PROBABLE ERRORS between PITCH DISCRIMINATION and INTELLIGENCE QUOTIENTS and PITCH DISCRIMINATION and ATTAINMENT QUOTIENTS

The determination of the following values of the coefficients of correlation was made by the use of the Pearson product-moment method. Tables III to X supplied the results on which the calculations were based.

CORRELATION COEFFICIENTS[1] between PITCH DISCRIMINATION

and

(1) Intelligence Quotients: $+0.33 \pm 0.10$

(2) Attainment Quotients in Reading: $+0.44 \pm 0.099$.

(3) Attainment Quotients in Vocabulary: $+0.35 \pm 0.107$

(4) Attainment Quotients in Spelling: $+0.27 \pm 0.113$

(5) Attainment Quotients in English[2]: $+0.41 \pm 0.102$

(6) Attainment Quotients in Addition: -0.14 ± 0.121

(7) Attainment Quotients in Arithmetic[3]: -0.064 ± 0.123

An examination of those coefficients shows that they have rather high probable errors and are somewhat low in numerical value. However, since the coefficients/

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[1] The carrying through of a second battery of Attainment Tests was unfortunately not possible, so that only "raw" correlation coefficients were obtained.

[2] See footnote on page 42.

[3] See footnote on page 46.

coefficients of correlation between pitch discrimination and reading and between pitch discrimination and English are more than four times their probable errors the values can be regarded as significant, and would appear to indicate a moderate degree of relationship between pitch discrimination and attainment in reading and between pitch discrimination and attainment in English.

The coefficient of correlation between pitch discrimination and intelligence quotients is rather low in value when compared with its probable error and is not regarded as having much significance. This also applies to the r values given under headings (3), (4), (6) and (7), the latter two being the only coefficients to show negative correspondence.

It was outwith the scope of the present investigation to carry through a special inquiry into the indicated positive relationship between attainment in reading and pitch discrimination.

The probability that a moderate relationship does exist is strengthened by the work of Ross[18] who, having examined a number of American children of approximately the same age as the Scottish, found, on correlating achievement in reading with pitch discrimination, a value for r of $+0.33 \pm 0.05$. The children in question were in Grade 5 which according to Macgregor[19] corresponds to the middle senior class in Scottish primary schools.

Although the co-efficient of correlation between pitch/

pitch-discrimination and intelligence quotients was not regarded as significant it must be mentioned that some investigators have found, on correcting the raw r, a high degree of positive correspondence between sense of pitch and estimated intelligence. However, in a number of those cases a doubtful method of estimating the intelligence of the pupils was employed. Reliance upon the rather arbitrary opinions of head teachers and class teachers cannot possibly compare in reliability with the results obtained from a well-standardized intelligence test.

The following investigators using the Seashore record for testing sense of pitch have found rather low coefficients of correlation between pitch discrimination and intelligence: -

Seashore[20], who reported that no test in his battery yielded with estimated intelligence a correlation coefficient that could be regarded as significant.

Hollingworth[21] having examined a group of 49 fifth-grade children whose median age was 10 years 4 months and all of whom had I.Q's above 135 found that in the pitch discrimination test - on the fifth grade norms - they had a mean percentile of 47. The conclusion at which she arrived was as follows:

"Above the level of intelligence required to understand and execute the directions for taking the Seashore tests (mental age of about ten years), performance in pitch discrimination, perception of intensity/

intensity, perception of consonance, and tonal memory is not symptomatic of intellectual endowment."

Kwalwasser[22] obtained the coefficient $+0.20 \pm 0.04$ as the correlation between sense of pitch and mental age. He does not indicate the intelligence test used.

Many other investigators examining college and university students have found similar results. The following two cases were selected as being typical:

Fracker and Howard[23] using for intelligence tests the Otis Self-Administering (higher examination) and Army Alpha reported a correlation with the Seashore pitch test of $.32 \pm .04$.

Salisbury and Smith[24] studied the relationship between pitch and a combined intelligence rating obtained from the Terman Group Test and the Thurstone Psychological Examination. The value of the coefficient obtained was $.31 \pm .05$.

Adverse criticism has been levelled against the results of earlier investigators who, having depended for estimates of the relative intelligence of the pupils on the opinions of headmasters and teachers, subsequently reported high positive correlation between intelligence and pitch discrimination, but it is also possible to criticise the r values obtained by many of the more recent researchers when engaged upon the same investigation.

In this connection it should be observed that although the pitch test of the Seashore battery has a reasonably high reliability and is considered the most reliable/

reliable of all the tests comprising the Seashore Measures of Musical Talent, it has been adversely criticised. Gilliland and Jensen[25] who have made a careful study of this particular test stated:

"The Seashore records have been standardized and are no doubt very satisfactory for the purpose for which they are used in school room tests.....But for laboratory experiments on pitch differences the phonograph records are not satisfactory."

It is evident that an important factor influencing the value of a correlation coefficient is the reliability of the tests which have been employed.

VOICE EXAMINATION

Before proceeding to an account of the singing-voices of the subjects, some facts regarding their speaking-voices will be given.

Speaking-Voice

Average Pitch Level or Voice "Key": Amid the rising and falling inflections of speech the ear perceives a constantly recurring sound which appears to "anchor" the voice to a certain level of pitch in a manner roughly comparable to the part played by the sound of the Tonic during the course of a melody. This/

This central sound of the speaking voice is subsequently referred to as "average pitch level or voice 'key'". In distinguishing it the ear is assisted by the harmonic superstructure - formed by upper partials - which faintly accompany the speech melody.

Observations made when the subjects were engaged in oral reading and on other occasions, showed that a number of different average pitch levels were present among the voices. Further study revealed the fact that although the children did not have fixed voice "keys" yet it was noticed that a subject spoke much more frequently at one particular pitch level than at any other. Tuning fork, pianoforte and the possession of absolute pitch made it possible to ascertain with a considerable degree of accuracy what that was in the case of each child.

The results of this examination are given in the following tables where the subject's number is shown in the column representing that particular semi-tone in which the average pitch level most frequently used by the subject occurred.

The standard of pitch employed is New Philharmonic (c' = 261 v.d.) and the notation of the intervals in column I of the Table is according to the Equal Temperament system of tuning.

(Table XI over) /

TABLE XI. AVERAGE PITCH LEVELS MOST FREQUENTLY EMPLOYED IN SPEECH.

B O Y S

Interval in which Average Pitch Level occurs[1]	Interval expressed in V.D. per sec.	Subject No.	Intelligence Quotient	Chronological Age. Yrs.	Chronological Age. Mths.	Mental Age in Yrs.	Mental Age in Mths.
e'♭ - e'	310.2-328.8	-	-	-	-	-	-
d' - e'♭	292.9-310.2	-	-	-	-	-	-
d'♭ - d'	276.5-292.9	26	96	10	11	10	5
		18	95	10	6	10	0
		27	92	10	4	9	6
		24	89	10	8	9	6
		21	89	11	1	9	10
		28	87	11	1	9	6
c' - d'♭	261·0-276.5	20	105	10	0	10	6
		29	103	9	10	10	2
		15	98	10	6	10	4
		22	96	10	9	10	4
b - c'	246.3-261·0	23	109	9	0	9	10
		14	102	11	0	11	2
		16	98	11	0	10	9
		17	95	11	2	10	7
		30	87	10	8	9	3
b♭ - b	232.6-246.3	25	102	10	3	10	6
a - b♭	219.5-232.6	-	-	-	-	-	-
a♭ - a	207.2-219.5	19	114	10	5	11	10

(TABLE XII over)/

[1] The notation is in accordance with the Equal Temperament system of tuning, and the standard of pitch employed, New Philharmonic (c' = 261 v.d.)

TABLE XII. AVERAGE PITCH LEVELS MOST FREQUENTLY EMPLOYED IN SPEECH.

GIRLS

Interval in which Average Pitch Level Occurs	Interval expressed in V.D. per sec.	Subject No.	Intelligence Quotient	Chronological Age Yrs.	Chronological Age Mths.	Mental Age in Yrs.	Mental Age in Mths.
$e'\flat$ - e'	310.2-328.8	9 12	92 89	10 10	6 8	9 9	8 6
d' - $e'\flat$	292.9-310.2	10 7	104 92	10 9	2 8	10 8	7 11
$d'\flat$ - d'	276.5-292.9	4 1 13 11	117 108 101 99	10 10 10 10	0 2 7 8	11 11 10 10	8 0 8 7
c' - $d'\flat$	261·0-276.5	5	105	10	3	10	9
b - c'	246.3-261·0	8 3 2 6	119 110 109 93	10 10 9 11	3 7 6 1	12 11 10 10	2 8 4 4
$b\flat$ - b	232.6-246.3	-	-	-	-	-	-
a - $b\flat$	219.5-232.6	-	-	-	-	-	-
$a\flat$ - a	207.2-219.5	-	-	-	-	-	-

Examination of the results in Tables XI and XII shows that with the exception of two boys and four girls the average pitch levels of speech used most often by the subjects occurred within the interval of a minor third, namely between b and d'.

Regarding/

Regarding the exceptions, the four girls had voice "keys" higher than d' and the two boys average pitch levels below b. However, in the case of girl number 10 and boy number 25 affection of larynx was the evident explanation. Shyness was partly responsible for the low pitch level used by subject number 19: he was however most developed both physically and mentally of the boys. The remaining exceptions were three of the smallest girls in class. Table XII shows their low mental ages.

Of the children examined, the sex of the subject did not appear to be a factor influencing the pitch level of the speaking voice.

Actually, the voices of boys and girls from ten to eleven years of age are very similar both as regards pitch level of speaking voice and - as will be indicated later - range of singing voice. There is a quality difference, but that will be dealt with in the section entitled "Quality of Speaking Voice" and also in the enquiry regarding the Singing Voice.

Reference to either Table, but especially to Table XI will show that there was evidence of a degree of correspondence between average pitch level of voice and mental age. Whether the average voice "key" of a child examined in reference to his chronological age could be regarded as an indication of the stage of his mental development is a question which could only be answered by a special inquiry.

Inflectional Movement in Speech: In the previous section, there were given the average levels of pitch used by the subjects in speech. The term 'average' was used designedly to indicate that inflectional movements were constantly occurring above and below those levels. The nature of those movements is now made the subject of investigation.

When the various movements used in speech sounds are examined, it is found that a threefold classification can be established. Every sound can be classified as a rising inflection, a falling inflection, or when neither of those is present, level intonation. Those types of phonation correspond respectively to the three modes in which the vocal cords can function during vibration. Rising inflectional movement in speech results from an increase in the frequency of vibration; falling inflections are due to a decrease, and level intonations to sustained vibrational rate.

When the subjects were observed regarding their use of inflection in speech it was apparent that the girls made more frequent use of such movements than did the boys, and moreover that their inflections were of greater pitch magnitude. As a result of this, the speaking voices of the girls were more expressive. It was noticed moreover, that, of the boys, the eight who were poorest in pitch discrimination seldom used any inflection during speech; their voices being of the monotone type. In oral reading, they were slow - and/

and hesitant in the production of syllable and word sounds, and frequently even omitted to lower the voice at ends of sentences.

In a subsequent section further inquiry will be made into the reason why the girls should make greater use of inflectional movement than the boys and why of the latter group those who had least ability in speech and in oral reading proved to be poorest in sense of pitch.

<u>Quality of Speaking Voice</u>: As regards quality of voice the girls were superior. The softer quality of their voices being due to the possession of vocal mechanism of smaller and of rather finer type.[1] This inborn difference is further accentuated by the amount of shouting done by boys in the course of play and which as a result of inflammations set up in the vocal cords and in the mucous membrane, fatty elastic tissue and thyro-arytenoid folds which underlie the cords, causes coarseness and huskiness to develop. This usually persists since it is seldom that the cords are allowed sufficient rest to regain their normal healthy condition. Fröschels[(26)] has mentioned that he frequently found evidence of improvement having taken place during the period of an exhausting illness when the subject's voice-mechanism had had a complete rest.

In/

1 This is dealt with in the section entitled, "Fluency in Speech."

In addition to mildness in quality, the girls' voices had greater clarity and musical ring or resonance. Those attributes were also present, although in a lesser degree, in the voices of the best pitch discriminators among the boys. The musical ring appeared to be due to the presence of high overtones. In the case of the eight boys poor in sense of pitch, their voices lacking those brightening harmonics were very dull and uninteresting in character.

<u>Fluency in Speech</u>: Here again the girls excel. Their greater fluency can no doubt be partly accounted for by their more delicate voice mechanisms requiring less effort to be put into operation.

At practically all ages the size of the larynx and length of the vocal cords is greater in the male than in the female. Negus[(27)] gives a table showing comparison of the internal antero-posterior diameters of larynxes and lengths of vocal cords of girls and boys from the infant period to puberty. From the results given in that table it is evident that girls possess smaller vocal organs than do boys of corresponding age. Not only are their larynxes smaller but the vocal cords are lighter and have slightly sharper edges. Such being the case, a lower air-pressure can be employed to make the cords vibrate, and also, during the period of one expiration a greater number of sounds can be produced.

As in speech, so in oral reading, the girls read at/

at greater speed than the boys. Ballard[28] evidently recognised a difference in reading ability between boys and girls in the elementary school since, in his "One-Minute Oral Reading Test" he employs two scales - one for boys and the other for girls - for the ascertainment of the children's reading ages. If a girl is to attain a reading quotient[1] equal to that obtained by a boy of similar age she must read a greater number of words in the space of one minute than is required of the boy.

Articulation: Two noticeable faults of the boys were: failure to open the mouth sufficiently and an inadequate use of the lips. In many cases this poorness in manipulation of the lip muscles was due to rigidity of the lower jaw, which in addition allowed only a small space between the teeth.

The girls were superior to the boys in articulation. There was a flexibility in their lip movements and complete freedom in the movement of the lower jaw. Thus, the space separating the upper and lower teeth although constantly varying was always adequate.

There were indications that this superiority of the girls in muscular control was not confined to lip movements. Thus it was observed how in gymnastic exercises the girls were more facile in action than the boys and appeared to possess better muscular co-ordination.

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1 Reading Quotient $= \frac{\text{Reading Age}}{\text{Chronological Age}} \times \frac{100}{1}$

SINGING VOICE.[1]

The subjects were examined as to range and quality of voice by the singing of songs learned in class. It was found that 'rounds' - on account of their moderate length - were most suitable for the purpose, as the child could sing the song several times in various keys without being fatigued.

The upper limit of the voice range was taken as that sound which marked the limit of tone production under normal conditions of pressure. It was not difficult to distinguish when that point in the compass was reached as the relatively greater effort required in singing above that limit was quite apparent. The lower limit was regarded as the lowest sound which the subject could produce with adequate volume and clarity.

TABLE XIII /

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[1] Examination of the singing voices took place after the subjects had been tested in pitch discrimination.

TABLE XIII. RANGE and QUALITY of SINGING VOICE

BOYS

Subject No.	Effective Voice Range	Observations on Voice	Pitch Accuracy
15	c′ - g″	Clear soft quality; moderate volume	Good
29	b - f″#	Good clear quality; moderate volume	Good
19	b♭ - f″	Huskiness throughout entire range; poor volume	Good
20	b♭ - f″	Slightly nasal and weak	Good
14	c′ - f″#	Fairly good quality; rather weak	Good
18	b - f″	Not powerful but a good degree of resonance in voice	Very good
28	b - f″	Weak and husky throughout. Would be declared the voice of a younger child.	Rather poor
17	c′# - f″#	Pleasant but poor in volume.	Fairly good
22	c′ - f″	Rather feeble; huskiness present above c″.	Fairly good
27	c′ - f″	Quite pleasant but thin. Impressed one as being the voice of a younger child.	Fairly good
16	c′ - e″♭	Poor in quality and volume	Rather poor
30	b - c″	Poor quality. Huskiness present throughout entire range.	Rather poor

25 (over)/

TABLE XIII (Contd.)

Subject No.	Effective Voice Range	Observations on Voice	Pitch Accuracy
25[1]	b♭ - d''	Very poor in quality and volume. Exceptional huskiness present throughout.	Very good
26	c' - e''	Consult "Notes on Table XIII."	Consult "Notes."
23	b - e''♭	"	"
24	c' - e''♭	"	Poor
21	b♭ - b'	"	Poor

Notes (over)/

[1] The comparatively low upper-limit of this subject's voice range was due to exceptional huskiness caused by: (1) Apparent chest and laryngeal weakness; (2) Excessive shouting when engaged in play.

Notes on Table XIII

Subject number 23: This boy was one of the most intelligent pupils in the class and one of the youngest. Taller and heavier than most of the other boys, he was however awkward and clumsy in his movements, this being due to an apparent lack of adequate muscular control.

The following is a brief account of a number of examinations made of this subject's singing voice[1], and carried through after he had been tested in pitch discrimination.

First Examination: Range of voice b - g'. Singing entirely with chest-voice mechanism. Unable to produce any sound in head-voice register. Sang the required songs in the octave below their proper pitch settings. His singing gave only an indication of the pitch-shape of the songs.

Second Examination: He successfully produced head-voice tone: it was however of rather peculiar quality and very weak. Using the head-voice mechanism he reached e''♭, often however, slipping back into the chest-voice register.

Third Examination: His upper limit appeared to be e''♭. It could be observed how he was endeavouring to gain control over the vocal ligaments in the new - head-voice - mechanism. He was helped in his estimations of tensions and relaxations by watching my/

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[1] In speech and in oral reading his voice was of very poor quality: it was entirely lacking in resonance and almost devoid of inflectional movement.

my hand which rose and fell in degrees corresponding to the pitch movements of the piano melody.

Increase in tension of the cords caused him much less difficulty than a decrease which was often misjudged so that his voice would fall in pitch considerably lower than he had intended.

Fourth Examination: He was possessed of a weak but clear head-voice register. It was evident that he was still learning to manipulate the voice muscles and occasionally became confused. His upper limit appeared to be $e''\flat$. In his singing he showed very little movement and control of the lips

Fifth Examination: Was able to sing class-songs using head-voice mechanism, and at the proper pitch settings. Tone weak but of a fair quality.

Had this subject been judged solely by the first examination it would have been said that he was exceptionally poor in pitch control. But, up to and at the time of that examination he had at his disposal one voice mechanism only - that of the chest voice. When he did succeed in producing head-voice tones it was found that his control of pitch when singing in that register was remarkably inproved. It appeared that his ability in the aural perception of pitch-differences developed along with his understanding of the new kinaesthetic sensations which he experienced.

Subject number 26: When first examined, this boy attempted to sing the songs in the octave below their/

their proper pitch settings. Those attempts were poor and gave only rough indications of the pitch movements of the melodies. Using only the chest-voice register his voice was of rather coarse quality.

After he had been taught to use the head-voice mechanism it was found that his control of pitch in singing was much better than it had been previously. His voice, found to have a range from c' to e'', was of fairly pleasant quality but was thin and poor in volume.

When he was learning to manipulate the voice-muscles employed in head-voice mechanism it was observed that the singing of descending passages frequently caused him trouble so that he would lapse into chest-voice register. This was due to insufficient discrimination in the control of the thyro-arytenoid muscles with the consequence that instead of leaving the external parts of those muscles in a state of relaxation and having only the innermost fibres in contraction, he would at times find himself unable to retain the outer parts in a passive condition and by bringing them also under contraction immediately produced chest-voice tones.[1]

Subject number 24: This boy had to be trained in the use of head-voice mechanism. When this was done/

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[1] The voice-mechanisms employed by children are discussed subsequently.

done, and he had gained considerable exercise in controlling the vocal cords, it was found that his voice although quite pleasant was thin, lacked resonance, and could undoubtedly have been regarded as the voice of a younger child. When unaccompanied, his song singing displayed extremely poor control of pitch. But, when assisted by the melody being played on the pianoforte as he sang, he did much better. He appeared to have a very poor memory for tones. The range of his voice was from c' to e''♭.

Subject number 21: It was obviously quite impossible for this boy to produce tones in the head-voice register. In his singing, chest-voice mechanism was solely employed, the consequence being that his attempts were always in the octave below the proper pitch settings of the songs. Whenever he encountered sounds too low in pitch for him to sing he employed in their stead a monotone. A similar method was adopted when the melody rose above his upper limit. His voice - range from b♭ to b' - was strong and rather strident in quality. Within the narrow limits of his compass he showed poor control of pitch.

The table which follows gives particulars regarding the singing-voices of the girls.

TABLE XIV/

TABLE XIV. RANGE and QUALITY of SINGING VOICE

GIRLS

Subject No.	Effective Voice Range	Observations on Voice	Pitch Accuracy
8	g - a''	Very good quality and volume throughout entire range. Undoubtedly the best of all the girls' voices. Such development of voice uncommon in a girl of her age.	Very good
6	c' - g''	Good clear quality; moderate volume	good
13	b - f''#	Clear pleasant quality; moderate volume.	Very good
7 [1]	b - f''#	Peculiar metallic ring in voice; good volume.	good
12	c' - f''	Clear and resonant; moderate volume. Impressed one as being the voice of a younger girl.	Very good
4	c' - f''	Feeble in volume but of pleasant quality	Very good
3.	a - d''	Slightly nasal and rather rough in quality; moderate volume	Fairly good
11.	e'b - g''	Clear and of moderate volume. Would be declared the voice of a younger child.	Fair
1.	c' - e''	Weak and husky	Good
9.	c' - e''	Thin in quality; poor in volume. The stage of development of the voice was that of a normal child's of lesser age.	Fair

10/

[1] A neurotic child.

TABLE XIV (Contd.)

Subject No.	Effective Voice Range	Observations on Voice	Pitch Accuracy
10	d′ - e″	Thin husky quality; poor volume	Fairly Good
5	d′♭ - e″♭	Fairly clear but lacking in strength	Good
2	c′ - d″	Poor quality; weak in volume	Good

Consideration of tables XIII and XIV shows that the average voice range of the girls was practically the same as that of the boys. It can be accepted that most children between the ages of ten and eleven years have an effective voice compass extending from b or c′ to e″ or f″.[1]

Examining the singing-voices of the children as to quality, it was found that the girls' voices, were on the whole clearer and softer. Of the boys' voices, many were marred by huskiness evidently caused by misuse of the vocal cords through excessive shouting in the course of play. Reference has already been made to this in the section dealing with the speaking-voice. Fröschels[2] has commented upon the incidence of huskiness among schoolchildren. He states that, as a result of investigations, it has been found that over 50% of all schoolchildren are husky in voice. This he attributes to various causes. Of these, shouting is the most obvious, but Fröschels asserts that the seed of the trouble may be sown during the period of infancy when the screaming of the young child may cause permanent injury to the delicate vocal cords. Again, the damage may occur in early childhood when children are taught at home, in kindergarten, and in school to sing songs which go far beyond their natural voice range. Moreover, in kindergarten and especially in school /

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1 A conclusion reached after examination of the voices of several hundred schoolchildren.

2 Op. cit.

school chorus-singing is introduced: this type of singing Fröschels declares to be very harmful as the children either consciously or unconsciously strive against one another thereby damaging the vocal ligaments. He advocates that chorus-singing should be replaced by group-singing.

Another important point of difference between the voices of the boys and girls was this: whereas several boys had to be taught to use the head-voice mechanism and practised in its manipulation such a necessity never arose with any of the girls as they could all sing in the head-voice register with evident ease. Moreover, they displayed greater flexibility of voice than the boys. Those points will be discussed later in greater detail.

Flatau and Gutzmann(29) and Paulsen(30) carried through investigations into the normal range of children's voices and obtained the following results:

Years of Age	Range of Boys' Voices	Range of Girls' Voices
6	d' - a'	d' - a'
7	d' - b' (= b'♭)	d' - c''
8	d' - h' (= b'♮)	d' - d''
9	d' - h'	c' - d''
10	c' - d''	c' - e''
11	h - d''	c' - f''
14	b - e''	h - f''
15	h - e''	h - f''

Weinberg(31) who made a similar inquiry submitted the following table:

(Table over)/

Years of Age	Boys' Voices		Girls' Voices	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
7	a - d'	h' - f''	xxb - cis'	b' - es''
8	g - eis' x	a' - f''	b - cis'	h' - f''
9	a - c'	c'' - f''	a - c'	c'' - gis''
10	g - c'	cis'' - g''	fis - h	e'' - fis''
11	g - c'	eis'' - gis''	gis - h	cis'' - f''
12	g - h	c'' - g''	f - h	b' - fis''
13	g - h	c'' - g''	c - h	g' - g''
14	g - h	cis'' - a''	es - h	f' - f''

x eis' = e'♯ ; h = b♮ ; cis'' = c''♯ ; gis'' = g''♯ .

xx b = b♭ ; cis' = c'♯ ; fis = f♯ ; es = e♭ .

Mechanisms/

MECHANISMS of the CHILD-VOICE

Before proceeding to an explanation of the voice-mechanisms of the child a few general statements concerning the voice will be made. It should be mentioned that in all matters concerning the functioning of the voice-mechanism the conclusions reached by Negus[27] has been accepted.

When air is expelled under pressure from the trachea it forces the vocal cords apart. The space thus formed between them, termed the glottis, is however very rapidly closed again as the glottic margins spring back bringing the vocal cords together. This rhythmical interruption of the air-floor produces sound in roughly the same manner as does a syren. Just as with that instrument, the more rapidly the air pulses succeed each other the greater the frequency of the produced sound.

It was formerly thought that variations in pitch were effected by stretching of the vocal cords. That explanation has been proved incorrect. In the first place, the vocal cords themselves have an exceptionally poor degree of elasticity and are so very extensible that it would be impossible for the artenoid cartilages to operate with the necessary amplitude of movement or for the postici muscles to possess sufficient force to effect that movement. Actually, the pitch of a vocal sound depends, as has already been stated, on the rapidity with which the stream of air from the trachea is/

is rhythmically interrupted; due to the elastic action of the glottic margins. This elasticity results from contraction of the thyro-arytenoid muscles which laterally bound the vocal cords. Negus[1] describes the action of those muscles in the following passage:

> "It appears to me that the elastic recoil of the glottic margins is supplied by the thyro-arytenoid muscle, and that the overlying band of elastic connective tissue, fat, and mucous membrane acts merely as a passive covering to afford protection to the muscle, just as the skin protects the muscles of the arm or leg. In man it is, of course, an advantage for the edges to be sharp, brilliant and pearly, and not irregular, as in certain states of disease."

It will thus be apparent, that in the following examination of the mechanisms of the child-voice, the most important factor is the manner of functioning of the thyro-arytenoid muscles.

<u>Chest Voice Mechanism</u>: The distinguishing feature of this mechanism is the contraction of the entire thyro-arytenoid muscles. This gives them a certain elasticity which can be varied by altering the degree of their contraction. As a result of total muscular elasticity and pressure of air from the trachea the principal movement of the glottic margins takes place in a horizontal plane; forced apart by the air and then recoiling. There is however a close relationship between the amount of contraction of the thyro-arytenoid muscles and the air-pressure employed. thus/

[1] Negus, op. cit., 373.

Thus, if it is the wish to increase the volume of a sound and at the same time retain constancy of pitch, the increase in air-pressure which is necessary, must be counterbalanced by a decrease in muscular contraction, otherwise a rise in pitch is evident.

Negus prefers to apply the term "normal" rather than the somewhat misleading designation of "chest-voice" to this particular voice-mechanism. However, when it is considered that most children up to the age of puberty employ this mechanism either very rarely, or never at all as is the case with those children in our best cathedral-choirs, it will be understood how the use of the term "normal" cannot be regarded favourably since it is liable to be accorded a meaning not intended by Negus[1].

The natural range of sounds available to a child using this mechanism is very limited, extending from b or c' to e' or f'. Those sounds are of a full quality but lack the clear ring of the head-voice tones. Some boys force this register[2] beyond its natural limit and ascend as high as c''. This is very bad for the voice, as the entire thyro-arytenoid muscles/

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1 Negus: op. cit., 419: "The normal register probably is the original mechanism of the Mammalian larynx, although it may have been superseded in some of the higher Apes, and possibly in the ancestors of Man. It seems that the falsetto is a late acquisition, due to specialised use of the thyro-arytenoid muscle."

2 The term "register" when applied to the voice signifies a range of sounds produced by one type of mechanism.

muscles are forced into an excessive state of contraction which then necessitates the employment of a relatively great air-pressure to separate the vocal cords. Such effort and strain make themselves apparent in the outward appearance; the face and neck becoming reddened; the throat swollen by the greatly increased air-pressure and the muscles of the throat tightened in the endeavour to secure maximum contraction of the thyro-arytenoid muscles. It is not surprising therefore that such sounds are of a strident and disagreeable quality.

As the natural range of the chest-voice mechanism is so limited, it is usual for teachers of singing to train children to use the head-voice mechanism almost exclusively.

<u>Head-Voice Mechanism</u>: It has already been stated that this is the important mechanism of the child-voice. That being so, the term applied to it by Negus of "falsetto" is unfortunate since it can conceivably be the cause of an erroneous impression being formed of this mechanism. As used by Negus, "falsetto" has the meaning - secondary in point of time, that is, a mechanism not originally used but acquired at a later period. However, there is no doubt that most people at the present time consider the term "falsetto" as meaning "false" and falsetto-mechanism as being a means of procuring tones beyond the natural compass of the voice.

? mmg

In/

In head-voice mechanism, not the entire thyro-arytenoid muscles but only the inner fibres immediately bounding the vocal cords are contracted, the outer parts - furthest from the cords - being left relaxed. As a résult, there is little elasticity of the glottic margins, and the force of endo-trachial air is sufficient to maintain constantly a narrow opening between the cords. The air which escapes through that aperture does not contribute to the production of vocal sound. However, the remainder of the air is rhythmically interrupted in its flow by the action of the glottic margins. In addition to the constantly open glottis, another result of the poorness in elasticity is the mode of action of the glottic margins. They are blown upwards by the pressure of air and then spring down again, their movement taking place in a vertical plane.

It has been observed that in this mechanism, as a result of the action of the posterior crico-arytenoid and the crico-thyroid muscles respectively, the vocal cords are elongated thereby rendering their margins thinner than they appear in the chest-voice mechanism.

As it is impossible to vary to any great extent the degree of elasticity of the glottic margins since only the inner fibres of the thyro-arytenoid muscles are contracted a rise in pitch is occasioned principally by increase in air-pressure.

The tones produced by the head-voice mechanism constitute/

constitute the true child-voice. Those tones are devoid of the least trace of harshness and are of a beautifully clear and ringing quality. The natural range extends from f' to f'' but by suitable voice exercises the head-voice register can be extended downwards to d' or c' thus including sounds of similar pitch and of superior quality to those in the limited chest-voice register which can consequently be discarded.

Voice Mechanism of the "Small Register": Although most children who have had voice training in school or choir employ only one mechanism - that of the head-voice - there are however a few who can sing g'' and even higher without undue effort. Such high-pitched sounds constitute what is termed the "small register." The essential point of difference between the voice mechanism employed for those sounds and that used in the head-voice register concerns the glottis. It has already been stated, that in the mechanism of the head-voice the vocal cords are blown apart along their entire length, forming an oval aperture. In the "small register" only the central part of the cords remains permanently open. As a result, there is not the same wastage of air as occurs in the head-voice so that a relatively small air-pressure suffices for those high sounds.

In other respects, the two mechanisms are identical.

On/

On page seventy-one, it was mentioned that a number of the boys who were examined had to be given special training before they were able to make use of the head-voice mechanism, whereas none of the girls required such help. This is not a unique occurrence but is on the contrary a common experience in most schools. Why should this be so?

There are two possible explanations which can be offered to account for the lack of use of the head-voice mechanism by a number of boys. The first is, that those children may prefer the deeper and rougher quality of the chest-voice tones to the clear and thinner sounds of the head-voice register, because of an idea that the former are more masculine in character: the consequence being an entire neglect of the head-voice mechanism. According to this view, head-voice tones could be produced at any time if the boys so desired. There is, however, another possible explanation which is, that such children fail to exercise that particular voice-mechanism not because they reject it as unboyish but by reason of their inability to establish it at all. In this mechanism a discrimination is called for in the control of the thyro-arytenoid muscles, for, as previously stated, only the internal fibres of those muscles are contracted, the outer parts being in a relaxed state. But why should it be that girls seldom appear to have any difficulty in achieving this discrimination? In a previous section/

section - that concerned with the speaking voice - a comparison was made of the larynxes of boys and girls. It was there remarked how girls possessed smaller and more delicate voice organs than boys of similar age. That superiority in structural quality of the larynx is considered the principal factor contributing to the ease with which girls employ the head-voice mechanism. Apart from that however, most girls show a preference for the soft and clear quality of the head-voice tones rather than for the more robust sounds of the chest-voice.

Sex/

Recognition of Direction in Pitch Differences: In the section devoted to results of the auditory tests, there was stated, with reference to the pitch discrimination test, that a number of the boys who were examined required considerable training before they could even be given practice tests. Actually, there were eight such individuals and they ultimately proved to be the poorest discriminators among the boys. As regards the girls, only one - number 11 - required similar training. All of those children found difficulty in judging the direction of a change in pitch. Burt(32) has mentioned that some of the schoolchildren whom he examined encountered this obstacle and he accounts for its occurrence as follows: "Successful judgments of direction of differences of pitch are not only intrinsically more difficult than judgments of mere difference, but also presuppose a knowledge of, and familiarity with, the meaning of the terms 'higher' and 'lower' as applied to the musical scale, - a knowledge which is not always available in children who have not enjoyed some degree of musical training." However, as the nine children in question had had the same music lessons, during their years at school, as the other subjects it was impossible to attribute their backwardness to lack of training. They might not, of course, have benefited to the same extent as the others. Certainly that would be true of/

of those boys - referred to in a previous section - who, at the time of the voice examination were found to be employing only the limited chest-voice register and who had to be taught the production of tones by head-voice mechanism. However, the root-cause appeared to be more fundamental than mere lack of benefit from school training. It was observed that the standard of general culture of those children was markedly inferior to that of the other subjects. Spearman(33) has remarked that auditory keenness results more from general culture than from practice.

When those children were engaged in learning to distinguish the direction of pitch differences it was found that on occasions when they were unable to reach a decision, humming or singing the two sounds in succession assisted them greatly; the kinaesthetic sensations from the larynx evidently being of considerable aid. During the subsequent practice tests and in the final examinations in pitch-discrimination humming or singing would not have been allowed had any of the subjects shown an inclination to do so.

<u>Superiority of Girls over Boys</u>: On page 33 it was stated that all of the girls - number 11 excepted - reached the approximate physiological threshold after fewer practice tests than the boys required. They did in fact show a decided superiority in the manner in which they carried through this particular test, displaying an ease and quickness of answer

lacked/

lacked by most members of the other group. Although it was impossible to draw a conclusion from the fact that the average limen of the girls was better than that of the boys - owing to the magnitude of the probable error of the difference between the two averages - yet, it could certainly be declared that the pitch discrimination test did not present the same difficulty to the girls as it did to the boys.

According to Seashore[20] there cannot be attributed to sex any constant effect upon capacity of pitch discrimination. Other investigators, such as Burt and Moore[34] have declared that sex is a factor of considerable influence. They concluded as a result of their investigation that, in sense of pitch, girls were superior to boys and, although not to the same extent, women to men. Of the English school-children whom they examined, the median value of the boys was found to be 6.0 v.d. and that of the girls 4.9 v.d. They considered that the median discrimination of girls marked the limit of all but 21 per cent. of boys, but that in the case of adults, 40 per cent. of men could distinguish smaller pitch differences than the median value for women.

Franklin Smith[35] also found that elementary schoolgirls were superior to boys in this test. The explanation which he offers to account for this is as follows:

"The superiority of elementary schoolgirls over elementary schoolboys may probably be accounted for by/

by the prevailing trait of aloofness of the pre-adolescent boy toward music. Those boys often regard music as a sort of frill for girls and, therefore, enter the test with less fervour than do the girls." Smith also mentioned that in practice series more than twice as many boys than girls were poor enough to require special individual training. He considered that this was "a distinct mark of superiority in the girls."

More recently, Farnsworth(36) has discussed this question of sex-difference in sense of pitch. He mentions that ten musicians having had the opportunity of listening to the Seashore battery of music tests[1] were asked in which of these they thought boys or girls should, as a group, excel. They - with only one exception - were of the opinion that girls should be superior in the pitch, memory, and consonance tests while boys should gain higher scores in time, intensity, and rhythm. The remaining musician considered that girls should surpass boys in all of the tests "since girls are naturally more musical." It was found that those people had based their selections upon ideas of social training similar to that suggested by Smith.[2] Farsworth concludes the section on sex difference thus:

"From his own observations, the writer hazards the /

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[1] The battery consists of six double-sided records produced by Columbia Graphophone, New York.

[2] See page 83.

the theory that the sex differences found in a schoolroom will vary with the personal qualities of and the methods employed by the music teachers. In other words, the writer follows somewhat the ideas of the musicians mentioned above. Under such training conditions as have existed in the past, the girls have been slightly more interested in musical tones, and the boys in mechanical noises. Certain teachers may be able to alter this state of affairs."[1]

Assistance from Kinaesthetic Sensations: From close observation of the children during examination and by questioning each individual immediately after completion of the final test in pitch discrimination it was apparent that many of the children, although not consciously aware of it at the time, had not relied entirely upon auditory sensations, but had been assisted in their judgments of pitch differences by muscular sensations in the larynx.

In the pitch discrimination tests, the wire used as standard was tuned to a' of 439 v.d. Consider now the position of that frequency in the voice registers of a child. In that of the chest-voice it lies above the normal upper limit and a sound of that pitch could only be produced by employing a high degree of contraction of the thyro-arytenoid muscles, and this, extremely difficult to attain during singing, is/

1 Farnsworth, op. cit., 346 f.

is certainly impossible during quiet listening. The position is quite different in the case of the other voice mechanism. In the head-voice register a sound of frequency 439 v.d. can be obtained very easily as it occurs in the lower part of the compass of that register.

This is significant because it means that a child who has been in the habit of using the chest-voice mechanism to produce sounds around that frequency cannot possibly obtain much help from muscular sensations in the larynx during discrimination tests at that pitch level. But, with children accustomed to employ the head-voice register, the contrary is the case. It is possible for them to derive considerable aid from kinaesthetic sensations, for, in that part of the register situated about the frequency 439 v.d. little effort is required in contracting only the inner fibres of the thyro-arytenoid muscles.

Now, it has previously been mentioned that girls make more frequent use of the head-voice mechanism than do boys.[1] This being so, and when it is considered that pitch differences occurring about the level 439 v.d. lie well within the head-voice register but not within the normal compass of the chest-voice, it will be evident that girls are in a position to gain assistance more readily than most boys from muscular sensations arising in the larynx.

It was subsequently observed when the children's voices/

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[1] See section entitled, "Mechanisms of the Child Voice."

voices were examined that those subjects who had never employed the head-voice mechanism or had seldom used it were individuals who had shown themselves to be poor in distinguishing pitch differences.

Regarding the part played by kinaesthetic sensations in such tests, Stumpf[37] states:

"If the muscular sense in the vocal organs is the same as a former tone that we have heard, we judge that it is the same tone. If we are told that a certain tone is A, we remember that a tone giving the same sensations is A. If the muscular sense changes in a definite way when we sing two tones, we say that the tones rise."

Stricker[38] depended upon muscular sensations in the larynx for reproducing in memory any particular tone or succession of tones. He considered that the mental reproduction of any sound - situated within the limits of the normal voice compass - was always accompanied by the appropriate adjustment of the voice muscles.

It is very probable that in the discrimination of pitch differences, kinaesthetic sensations combine with the undoubtedly more important auditory sensations to form as Smith[1] has stated "an auditory-vocal perception."

In the investigation carried through by the writer it was found that subjects who were very poor in sense of pitch employed what was practically a monotone/

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[1] Smith, F.O., op. cit., 89.

monotone in speech, whereas those children who were best in pitch discrimination made much use of inflectional movement. The amplitude of inflections in the speaking voice and the frequency with which they were employed appeared to be determined by a subject's capacity for pitch discrimination.

In the section devoted to the speaking-voice it was stated that the girls made greater use of inflectional movement in speech than the boys.

Inflections being changes in pitch result from action of the voice muscles so that girls not only gain more frequent practice in controlling the muscles but also benefit by experiencing and interpreting the muscular sensations resulting from those variations. Most boys are not in such a fortunate position and as a result require opportunities to become more familiar with muscular sensations in the larynx and to learn to interpret them correctly. This is probably one reason why a greater number of practice tests in pitch discrimination is necessary for most boys than for girls.

Of even greater importance, however, is the fact that a girl, hearing the inflectional changes in her own voice, actually furnishes herself with opportunities of practice in distinguishing differences in auditory sensations. Moreover, by hearing the speech of her girl companions further practice is obtained. It is not suggested that this makes girls superior to boys in pitch discrimination but merely that they, having had/

had considerable training, do not require so many practice tests.

That there was an intimate relationship between hearing and the voice was shown by Vance (39) who, as Watt (40) mentions, found that the most acute discrimination of pitch occurred in that range of frequency most often used in speech.

Since girls appear to gain much training by their use of inflectional movements in speech it is reasonable to inquire why they should employ inflections to a greater extent than most boys do. Smith[1] would doubtless have accounted for this by stating that boys consider the use of such variations in voice-pitch as girlish and consequently to be carefully regulated as regards their occurrence and amplitude. It is however probable that a deeper reason exists.

Darwin (41), as Erickson (42) has stated, considered that emotional urge seeking outward expression led to the development of the voice. According to this theory, emotional experiences will, if allowed free expression produce alterations of the voice in pitch, quality, intensity or speed of utterance, or simultaneously in more than one of those elements. In the case of adults, however, it is seldom that the emotions are allowed free expression so that the adult voice is not the best medium for such study. Opportunity to observe the effect upon the voice of freely expressed emotion is possible in the case of children in the elementary/

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[1] Smith, op. cit.

elementary school, where it is found that in general, girls' voices display such variations more frequently than do those of boys. This difference, possibly due in part to repression by the boys, is more probably a result of the more emotional nature of the girls.

If, as Darwin stated, the voice is the instrument developed to give expression to the emotions, and if girls are in nature more emotional than boys then we should expect that in infancy, girls would commence to utter sounds and speak at an earlier age than boys. This does appear to be the case. Seth and Guthrie(43) mention that Bateman, having observed the development of speech of a number of infants found that 87% of the girls had succeeded in producing their first spoken word at the end of the first year whereas only 50% of the boys had achieved this.

Stern(44) dealing with the same question states as follows: "On the whole the quick reaction to what has been heard with corresponding utterances is, in proportion, most frequently found in girls, whilst the longer storing up of impressions and only indirect imitation is more common in boys." He also mentions that girls at two years of age have a speaking vocabulary of about three hundred words but that boys only attain this at the age of two and a half years.

Mead(45) also declares that "boys, whether normal or feeble-minded, learn to walk and talk later than girls." It cannot be assumed from this that girls/

girls have more intelligence than boys for as Preyer(46) has stated, "no special activity of intellect is proved by the quick learning of speech."

Thus, it is considered that the greater number and amplitude of inflectional movements in the speech of girls is a direct result of their more emotional and less repressive nature.

Summary/

SUMMARY and CONCLUSIONS

In this investigation, thirty boys and girls in the middle senior class of an Edinburgh elementary school were examined in:

I. (a) Upper limit of tonal hearing;

(b) Lower limit of tonal hearing;

(c) Pitch-discrimination;

(d) Speaking voice;

(e) Singing voice.

They were also given as a group:

II. (a) An intelligence test (Otis, Primary, Form A);

(b) Edinburgh Education Committee's attainment tests in: reading, spelling, vocabulary, addition, subtraction, multiplication and division.

As the investigation covered a very wide field, only the principal conclusions will be stated.

1. In the perception of high frequency sounds boys and girls were equally successful. The average upper limit of each group was approximately 18,670 v.d.

2. In the perception of low frequency sounds neither group displayed a superiority. The average lower limit of boys and that of girls was 18.2 v.d. The children regarded this as the most difficult test as they found it hard to distinguish the fundamental from the octave vibration.

3. The Pitch discrimination test presented less difficulty to the girls than to the boys. They required fewer practice tests and their average threshold was 7.5 v.d. (M.V. 1.8 v.d.; extremes 4.6 and/

and 11.8 v.d.), whereas that of the boys was 9.3 v.d. (M.V. 3.2 v.d.; extremes 4.0 and 20.0).

4. Of the correlation coefficients calculated between Pitch discrimination and
(a) intelligemce quotients, and
(b) attainment quotients, the most significant was that between pitch discrimination and A.Q.'s in reading where the value of r was found to be $+0.44 \pm 0.099$.

5. From examination of the speaking voice it was concluded that the voices of boys and girls were very similar as regards the average pitch levels most frequently employed but that in (a) inflectional movement; (b) quality; (c) fluency; and (d) articulation, the girls were superior.

6. Examination of the singing voice showed that as regards effective voice compass there was no difference between boys and girls. The average range extended from b or c′ to e″ or f″.

7. In quality, the girls' singing voices were superior to those of the boys. Among the latter, many were marred by huskiness resulting from inflammations set up in the vocal cords by excessive shouting.

8. Girls showed greater command over the head-voice mechanism.

9. In discrimination of pitch many children gained assistance from kinaesthetic sensations arising in the larynx.

10.. There appeared to be a considerable degree of relationship between capacity for pitch discrimination and the amplitude and frequency of inflectional movements employed in speech.

11. Girls apparently derive appreciable training from their frequent use of inflections in speech. As a result they require fewer practice tests in pitch discrimination.

12. Their greater use of inflectional movement is traceable to their more emotional and less repressive nature.

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